A METHODOLOGY FOR DETERMINING BMC4I PARTICIPATING UNITS (PUs) INTEROPERABILITY REQUIREMENTS

Presented to the:

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EXECUTIVE SUMMARY

This paper describes a methodology that determines System Interoperability Requirements for forces, participating in Joint Operations in the areas of Battle Management Command, Control, Communications, Computer and Intelligence (BMC4I). From the perspective of Joint Force operations, the system interoperability requirements are determined at the force level as follows:

a. Command and Control Level to include Force Planning and Coordination;

   1. Develop Defense Design,

   2. Set and Enforce Rules Of Engagement,

   3. Respond to Battlefield Changes,

   4. Report Force Status.

b. Weapon Level Command and Control to include Force Execution;

   1. Control Sensors and Weapons,

   2. Direct System Engagements,

   3. Report System Engagement Status.

Actual system interoperability requirements are obtained from an iterative process. The process employs Operational Architectures, Modeling and Simulation Tools, Distributive Interactive Simulations, Hardware-in-the-Loop, and Plug and Play Capabilities.

The methodology, that determines the BMC4I participating unit's force level interoperability requirements, consists of a set of logical steps that are iterative by design. It provides insights, reliable and useable estimates of numerical measures of force level system requirements at several levels of command. ***The process is not trivial; the expected level of effort could be significant.*** The methodology consists of five basic stages considered necessary to achieve valid results. These stages are:

a. Determination of force level system requirements;

b. Determination of force level system capability;

c. Analysis of force level system capability;

d. Determination of force level system requirements by battle overview or specific scenarios such as Southwest/Northeast Asian;

e. Allocation of force level system requirements to participating units.

This methodology can be used by Program Managers (PM) for determining force level BMC4I system interoperability requirements for individual participating units in the battle force. In addition, once the participating unit's performance has been defined, the methodology generates quantitative data bases that become useful tools for BMC4I system suite selection. Once alternative suites have been defined, they can be analyzed in terms of the specific participating unit's performance capability versus cost.

INTRODUCTION

The Joint Theater Air Missile Defense Organization (JTAMDO), of the Joint Staff, is responsible for developing the Operational Architecture for Theater Air Missile Defense (TAMD). The BMC4I Operational Architecture is defined as a description of tasks, operational elements, and information flows required to accomplish warfighting functions. This methodology employs the following Operational Architecture techniques to develop and select performance options for participating units:

a. Operational Concept Diagram;

b. Command Relationship Chart;

c. IDEF0 Activity/Functional Model;

d. Participating Unit Information Exchange Requirements;

e. Required Participating Unit Capabilities Matrix; and

f. Participating Unit Node Connectivity Model.

The goal of the methodology is to select several options for BMC4I performance requirements and allocate the corresponding BMC4I requirements to participating units to meet the requirements for each performance option. A quantitative data base could be provided as a tool for selecting and implementing alternative suites for participating units. It is in this context that the phrase ***"participating unit requirements"*** is used. In addition, once the participating unit's requirements have been established, alternative suites are generated. The alternative suites can be compared in terms of system capability and effectiveness versus cost.

PROBLEM STATEMENT

The Battle Management Command, Control, Communications, Computers, and Intelligence structure glues the Battle Force together. BMC4I requirements enable the interoperability of participating units. During the employment of offensive and defensive operations, BMC4I implementation emphasizes the synergistic benefits derived from the processes of joint planning, joint coordination, and joint execution[1]. The synergistic benefit imparted to the battle force is that the cooperative participation of individual participating units is such, that the total effect of the battle force is greater then the sum of the individual participating units (capabilities) acting independently, i.e.,

$$\overline{BMC4I} + \sum_{X=1}^{n} \overline{PUx} > \sum_{X=1}^{n} \overline{PUx}$$

The task is to establish a set of battle force BMC4I requirements, allocate requirements to the mission areas across the Battle Force, and allocate the functional requirements to the individual participating units. It should be noted that allocating BMC4I requirements among the participating units is a difficult task. The difficulty arises from a defense in depth concept that implies multiple participating units with the same redundant requirements, overlapping areas of responsibilities associated with the battle force participating units, and common capabilities among PUs.

The key to this effort is to establish participating unit BMC4I requirements with the necessary definitions, assumptions and tools expressed at the start. In particular, it is necessary to have established a clear and agreed upon set of battle force BMC4I requirements based upon battle force missions and their corresponding objectives. It is a fundamental task requirement that the definitions be expressed in measurable form so that the appropriate measures of battle force capability can be obtained. The measures of performance[2] include, but are not limited to, the following:

a. Participating unit (network node) connectivity performance;

b. Network/data link throughput (information) performance;

   1. Capacity: the rate at which data may be passed over time;

   2. Network loading performance:

      (a) Overload condition: where the volume of data being exchanged exceeds the transmit capability;

      (b) Under utilization condition: system data rate/message load is

less than its full capacity and messages are waiting in queues to be transmitted due to polling schemes;

(c) Data latency performance (timely arrival of the information);

(1) Latency of Observation,

(2) Latency of Measurement/Performance,

(3) Latency of Transmission Receipt.

d. Estimates of Information Utilization;

1. Estimate total data/information flow rate;

2. Estimates of number/types of processing errors;

(a) Track steals,

(b0 Dropped tracks,

(c) Misclassification,

(d) Fratricide,

(e) Duplicate engagements.

PROBLEM SOLUTION

A methodology, that determines BMC4I requirements for participating units should consist of a set of logical functions. It must provide insights and verifiable estimates and assessments of the defined BMC4I force requirements at each level. ***This process is not trivial; the expected level of effort could be significant.*** The actual requirements are obtained from an evolutionary process that employs Modeling and Simulation Tools in the virtual space and includes Distributive Interactive Simulations, Hardware-in-the-Loop, and Plug and Play Capabilities.

A BMC4I requirements methodology has been developed that implements the above discussed measures of performance to establish battle force BMC4I requirements. The methodology consists of five stages necessary to derive participating unit BMC4I requirements. At the Battle Force Command and Control and Weapon Control level the five stages, illustrated in Figures 1 through 5, include the following:

a. Determination of force level system requirements;

b. Determination of force level system capability;

c. Analysis of force level system capability;

d. Determination of participating unit requirements for the postulated battle overview for specific scenarios such as Southwest/Northeast Asian; and

e. Allocation of force level requirements to participating units.

The details of each stage are shown in the flow charts presented in Figures 1 through 5. The flow charts illustrate the complexity of the BMC4I system interoperability requirements methodology.

Figure 1, Stage 1, provides the process for deriving candidate force level BMC4I system interoperability requirements; allocating the requirements to BMC4I systems; and deriving BMC4I system interoperability performance criteria.

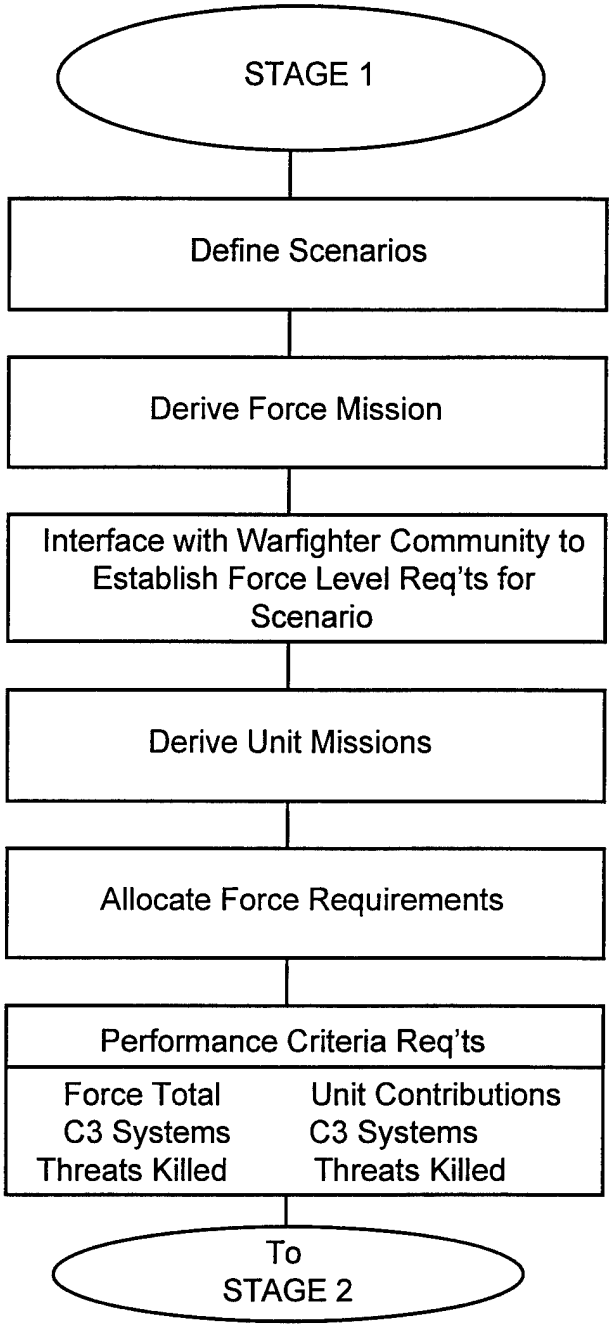

Figure 1
Stage 1 - Determination Of Force Level Requirements

Figure 2, provides the process for selecting appropriate scenarios and candidate Modeling and Simulation (M&S) tools. Stage 2, executes the M&S tools and gathers data for interoperability requirements analysis. The results of this process produces a candidate baseline force capability defined in terms of Threat Kill versus BMC4I capability.

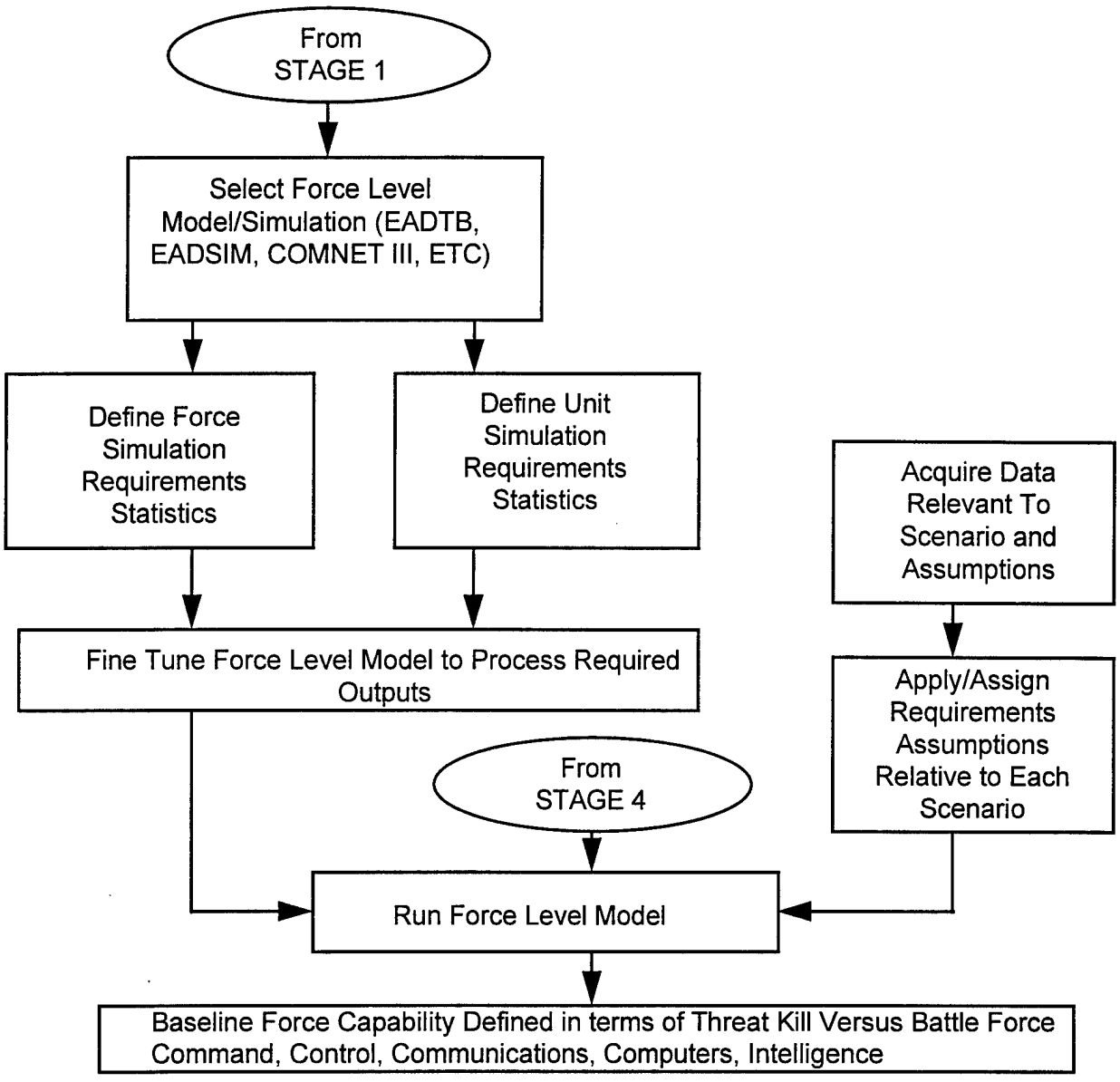

Figure 2
Stage 2 - Determination Of Force Level Capabilities

Figure 3, Stage 3, provides the analysis process. If the analysis reveals that the force mission interoperability requirements have been met, then the contributionfrom each participating unit is recorded. The methodology continues into Stage 5 which determines the overall battle force interoperability requirements. If the force mission has not been met, the mthodology continues into Stage 4.

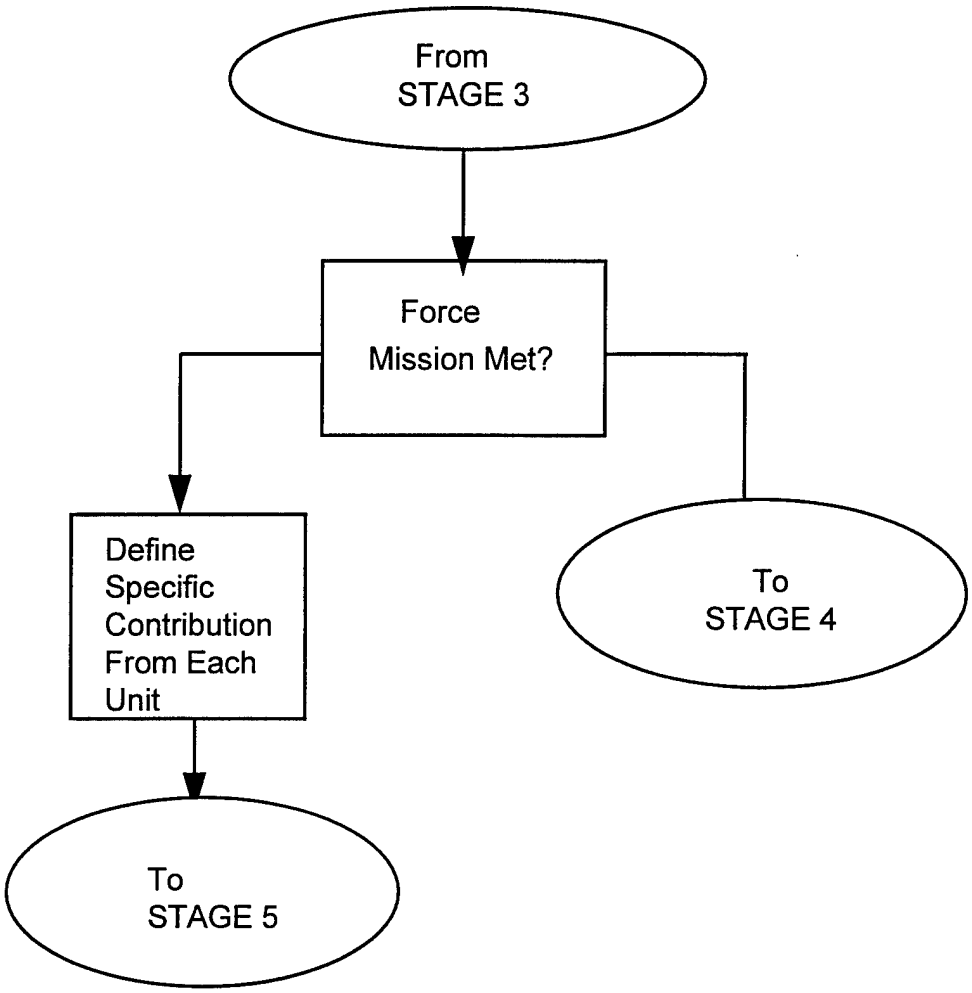

Figure 3
Stage 3 - Analysis Of Force Level Capabilities

Figure 4, postulates additional system capabilities to meet the estimated BMC4I interoperability requirements. The methodology returns to Stage 2, inputs the postulated additional capability, and iterates the M&S tools.

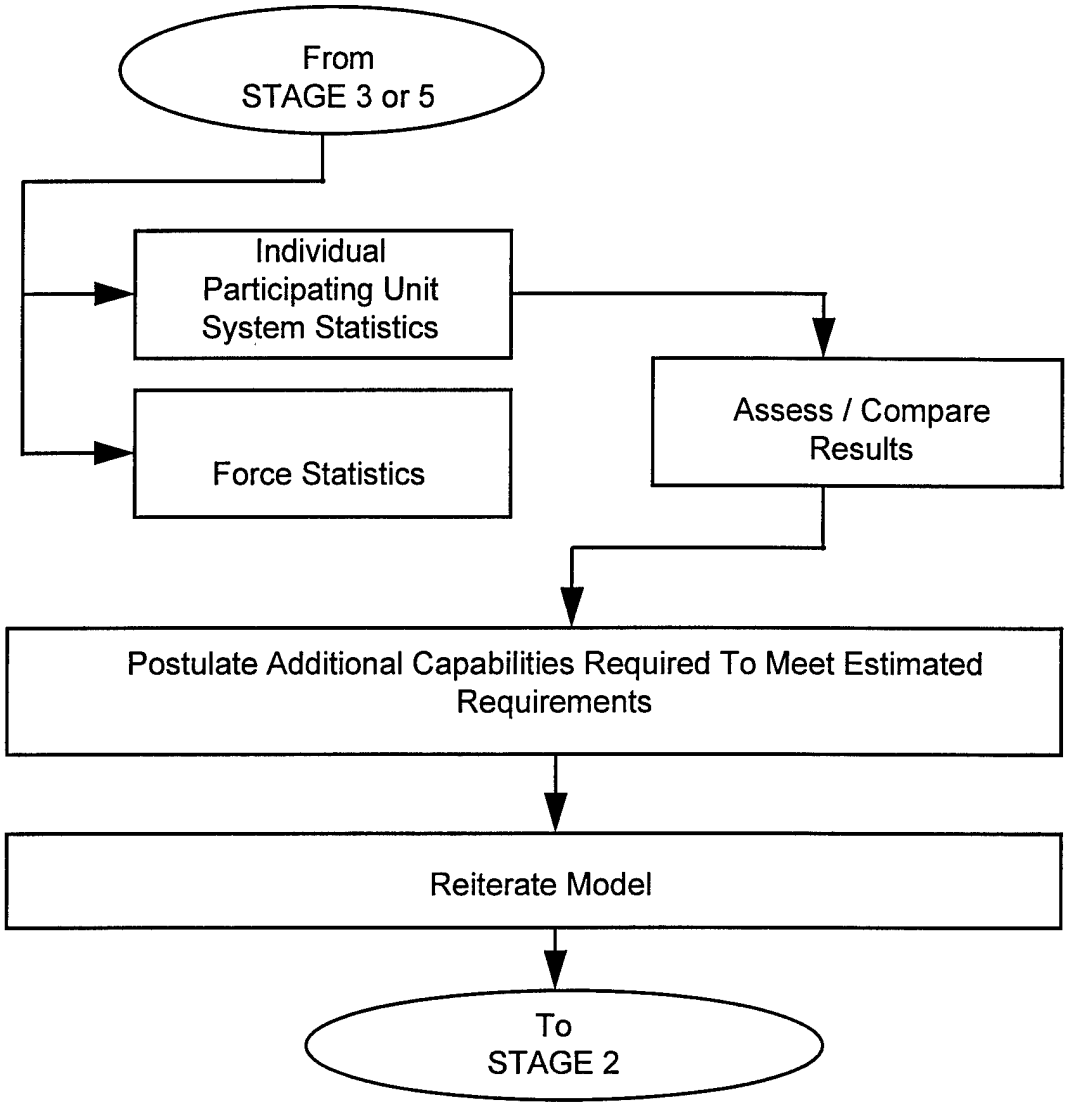

Figure 4
Stage 4 - Determination of TAMD System Requirements

Figure 5, presents the process that examines the derived interoperability requirements across all scenarios and allocates the postulated requirements to the participating units. The force level M&S are executed to validate the system interoperability requirements. If all system requirements for all scenarios are met, the set of BMC4I system requirements are defined for implementation. Otherwise, the scenario(s) that were found to be deficient are identified and the methodology continues in Stage 4.

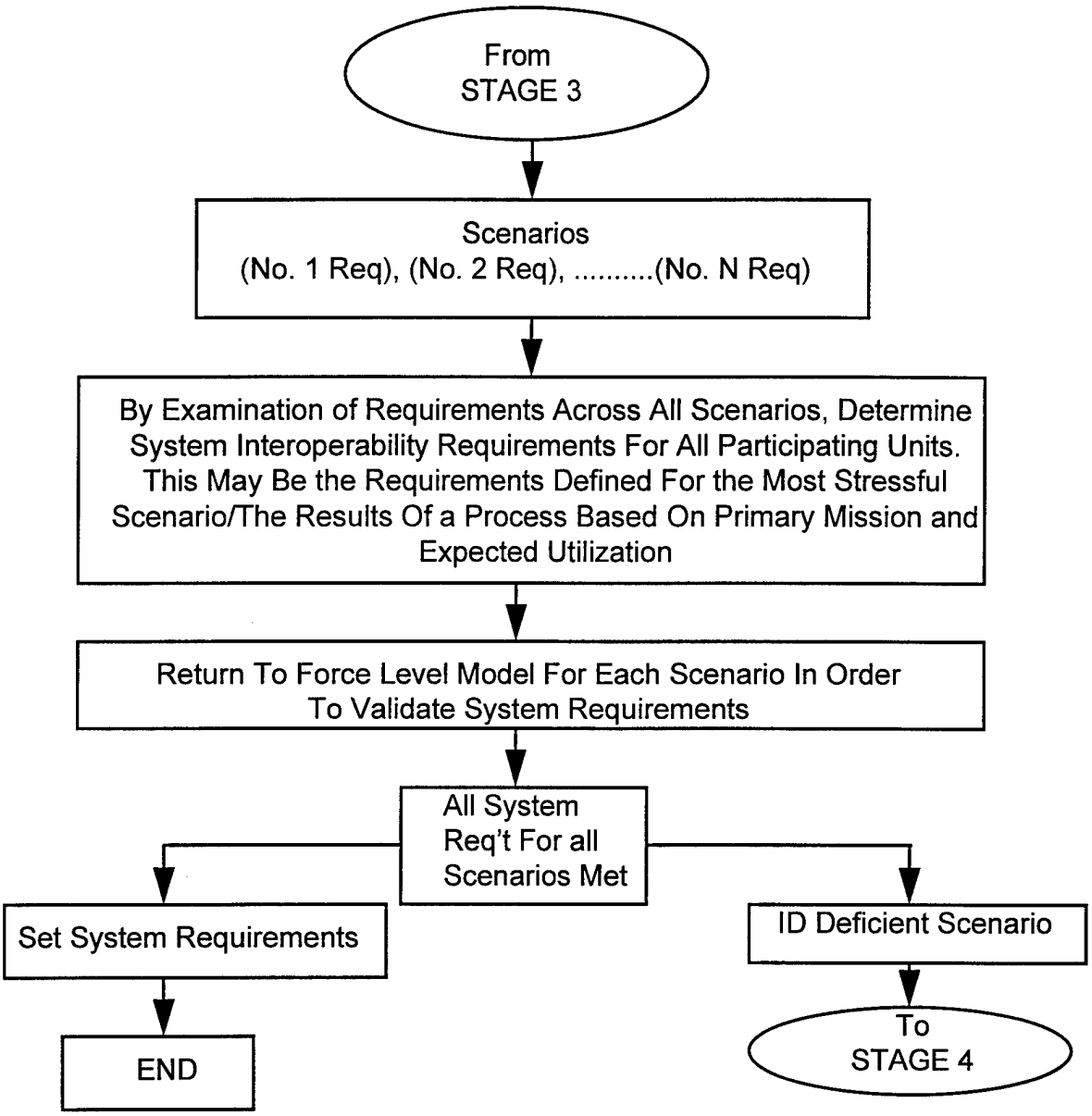

Figure 5
Stage 5 - Overall Battle Force Requirements Determination

DEMONSTRATION

This section presents a demonstration of the methodology which begins with the following scenario or battle overview. Two neutral cities are under attack from Red Forces. Blue Force have arrived on station with the mission of defending the neutral cities by countering the Theater Air and Missile threat. The threat consists of two elements: aircraft (manned and unmanned) and missiles (including ballistic missiles, overland cruise missiles, air-to-air missiles, and air-to-surface missiles). Individual aircraft and theater missiles pose a significant threat to friendly forces. The battle force mission, ideally, would be to destroy or degrade the adversary's command and control and air defense capabilities that includes identified fuel sites, air bases, and supply sites. Failing that, system self defense capability would be used to engage inbound threats.

Therefore, the battle force mission, derived from the scenario or battle overview, is to destroy and degrade the adversaries command and control, and air defense resources and capabilities.

The next step is to determine the battle force requirements. The force requirements follow directly from the battle force mission, but are more specific. For this sample battle force overview, ***Joint Forces Operation***, the battle force is required to defend the following high value assets:

a. Lines of communications,

b. Logistic facilities (ports, air bases, and marshaling areas), and

c. Large civilian population centers.

In an attempt to quantify the battle force mission, the following battle force command, control, and communication requirements have been selected for implementation:

a. Reduced battle force reaction time,

b. Reduce and minimize the number of enemy leakers,

c. Communication availability on demand, and

d. Effective allocation and utilization of battle force weapons inventory.

This demonstration will focus on the implementation of "communication availability on demand" requirement in terms of participating unit's communication timeliness requirements; i.e., information exchange requirements[3] between participating units within the battle force. The timeliness requirements for information exchanged are real-time, near real-time, and non-real-time. These timeliness requirements are defined in The Theater Air Defense Capstone Requirements[1] Document.

a. "Real-time is the timeliness of data or information that has been delayed by electronic communication. The implication is that there are no noticeable changes in the arrival of the information. Real-time information is exchanged over the Joint Composite Tracking Network. Consequently, real-time information exchange requires the information to be exchanged in $\leq$ 0.5 seconds."

b. "Near-real-time is the timeliness of data or information that has been delayed by the time required for electronic communication and automatic data processing. The implication is that there are no significant delays. Near-Real-Time information is exchanged over the Joint Data Network. Consequently, near real-time information exchange requires the information to be exchanged in $\leq$ 12 seconds."

c. "Non-real-time information exchange is assumed to mean time greater than near-real-time (Joint Publication 1-02). Non-Real-Time information is exchanged over the Joint Planning Network. Consequently, non-real-time information exchange is any information exchanged in > 12 seconds."

The next step in the methodology is to derive, from the battle force mission, each participating unit's mission. Each individual participating unit's mission is a function of two main factors. The first of these two factors is the participating unit's designed mission, which as it's name implies, is determined form the units original design. A design mission for an AEGIS ship class is to provide Anti-Air Warfare (AAW) threat detection, localization, combat identification/discrimination/classification (Positive Hostile ID), attack and kill capabilities against all types of enemy aircraft.

The second factor is the overview or scenario. The scenario can modify the participating units' battle force missions as a consequence of different alternative options. The extent of the unit's actual battle force mission is dependent upon the number of battle force options and the availability of units currently supporting other aspects of the battle force mission. For example, an AEGIS Cruiser, assigned to a carrier battle group, has area AAW as its primary mission. It's modified overview mission could be supporting the Joint Forces Defense-in-Depth operations. The AEGIS Cruiser would be employed as part of an active air defense force in a manner that provides multiple "shot opportunities" along the entire flight path or trajectory of in bound hostile aircraft or missiles. The best way to demonstrate the development of an

individual participating unit is to consider an example.

AEGIS Cruiser --- SAMPLE OVERVIEW

Design Mission

An AEGIS Cruiser, assigned to a carrier battle group, provides:

a. On an individual participating unit level, target detection, localization, identification, classification attack and kill capabilities;

b. Area AAW in a support role with other participating units; and

c. Ownship self-defense against all types of threats.

Overview Modified Mission

a. Support the Joint Forces Defense-in-Depth operations.

Unit Mission

a. Provide support to the Joint Forces Defense-in-Depth operations;

b. Provide area AAW in a support role with other participating units;

c. Provide for ownship's self defense against all types of threats.

AEGIS has taken on the additional responsibility of supporting the Joint Forces Defense-in-Depth operations as compared to its design mission of area AAW.

Now that the participating units missions have been specified, attention is focused on determining the communication suite objectives for each participating unit. The communication objectives for each participating unit is the maximum percentage of communication deficiencies that a participating unit can sustain and still be expected to perform its unit mission. In order to determine the communication objectives for each participating unit, a process had to be developed that allowed for the quantification of each participating unit's communication capacity.

The process developed consists of three parts, the first of which is the formation of the participating unit's ***baseline equipment table.*** A baseline equipment table is a listing, in table form, of the communication suites aboard a participating unit. For the AEGIS platform used in the sample overview, the baseline equipment table is shown in Table 1, where the X's represent the communication suite of equipment; and Y's represent the communication channels and/or corresponding communication circuits.

TABLE 1. AEGIS COMMUNICATIONS BASELINE EQUIPMENT TABLE			
COMM SYSTEM	DATA LINKS	NUMBER OF CHANNELS OR CIRCUITS	COMMENTS
JOINT COMPOSITE TRACKING NETWORK	X1	Y1	COOPERATIVE ENGAGEMENT CAPABILITY
JOINT DATA NETWORK	X2 X3	Y2 Y3	LINK 11 TADIL B LINK 16 TADIL J
BROADCAST	X4 X5	Y4 Y5	TACT INTEL BROADCAST SYSTEM TRAP DATA DISTRIBUTIVE SYSTEM

After a baseline equipment table has been formed for each participating unit in the battle force, it is time to generate the second part of the quantification process, the ***unit mission minimum equipment table.*** As its name implies, this table list the minimum equipment that a participating unit must have to perform its unit mission. The minimum must not exceed the baseline level. If a participating unit's communication suite has performance deficiencies, its baseline capability can be increased. Ideally, the temporary equipment allocation identifies the need for additional systems requirements and capabilities.

The minimum equipment table is not a concrete item, but is, rather, set by the user's experience with the participating units mission. For AEGIS the minimum equipment level was set as shown in Table 2. Using the AEGIS unit's mission, it is fairly easy to see how the minimum equipment levels were set in terms of the minimum number of communication channels or circuits. The minimum number of communication channels or circuits is a judgment call on the part of the user of this methodology. Since this methodology calls for several iterations about the baseline, one will know if his choice of the minimum number of channels or circuits was too high or too low for the specific overview.

The Third part of this process is one that actually quantifies the participating unit's communications capabilities. Quantifying the AEGIS communication system performance requires the development and implementation of sets of communications measures of performance and effectiveness. Reference (2), *Interoperability Assessment/Analysis Tool*, provides a methodology that quantifies BMC4I Systems

Interoperability[5]. It should be noted at this point, that the Interoperability Assessment Tool methodology was used to quantify the AEGIS communication system objectives. The methodology identifies and defines nine BMC4I Interoperability system components (Requirements, Standards, Data Elements, Node Connectivity, Protocol, Information Flow, Latency, Interpretation and Information Utilization). The next step in the quantification process is to match up the AEGIS Baseline Communications Minimum Equipment Table with the nine interoperability components. The results of this step enables the selection of the specific measures of performance and effectiveness that will be used in quantifying AEGIS communication system performance.

TABLE 2. AEGIS BASELINE COMMUNICATIONS MINIMUM EQUIPMENT TABLE

COMM SYSTEM	DATA LINKS	# OF CHANNELS OR CIRCUITS	COMMENTS
JOINT COMPOSITE TRACKING NETWORK	X1	Y1	COOPERATIVE ENGAGEMENT CAPABILITY
JOINT DATA NETWORK	X2 X3	Y2 Y3	LINK 11 TADIL B LINK 16 TADIL J
BROADCAST	X4 X5	Y4 Y5	TACT INTEL BRDCST SYSTEM TRAP DATA DISTRIB SYSTEM

The next step in the process is to obtain a set of computer models and simulations that best fit the Interoperability Assessment Tool methodology. The next step substitutes the following baseline input data into a Battle Force Simulation(s) such as Extended Air Defense Simulation (EADSIM), or Extended Air Defense Testbed (EADTB).

a. Real-Time-Information Exchange Requirements < 0.5 seconds;

b. Near-Real-Time Information Exchange Requirements $\leq$ 12 seconds; and

c. Non-Real-Time Information Exchange Requirements > 12 seconds.

It should be noted that there are many other models and simulations that will work well with the Interoperability Assessment/Analysis Tool. The EADTB tool was selected for the following reasons:

a. It was specifically designed with BMC4I communication requirements in mind, and
b. It provides a perfect fit with the Interoperability Assessment/Analysis Tool.

It should be reiterated, however, that the specific model chosen, while important, is not vital to the Interoperability Assessment/Analysis tool.

SUMMARY

This paper has presented and described a methodology that identifies, quantifies, and establishes Battle Force BMC4I Participating Unit requirements. The methodology presented in this paper has the potential for:

a. Identifying, isolating and resolving Battle Force BMC4I problem areas and issues, and

b. Setting participating units BMC4I system requirements.

The methodology is currently being implemented. Once results have been obtained and analyzed the corresponding participating unit requirements will be published. After the methodology has been refined, it will be capable of setting combat system requirements across all Battle Force Warfare Areas for all types of participating units. The logical expansion of this methodology derives "required forces" for given scenarios. The first successful iteration will establish that an acceptable level of performance has been determined. Further iterations may be necessary to establish the most cost effective asset utilization; e.g., a Patriot Missile Battery or an AEGIS Cruiser/Destroyer could be reassigned to other missions.

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